

METHOD FOR ENSURING CONTENT PROTECTION AND SUBSCRIPTION COMPLIANCE

RELATED APPLICATIONS

This is a continuation-in-part of U.S. patent application serial no. 09/770,877, filed

5 January 26, 2001, incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to multicast data encryption.

2. Description of the Related Art

10 Protecting copyrights of content owners and subscription rights of providers of the content poses considerable challenges in the digital age, particularly to content that is "streamed" to users over the Internet. In contrast to more conventional content download, in streaming paradigms the data that is being transmitted can be used by the recipient before the end of the file has been received. For time-dependent content such as music 15 or videos, streaming requires mechanisms to ensure that data is available when needed.

"Streaming" is one common application of multicasting. In multicasting, multiple users can receive the same stream roughly simultaneously. Multicasting thus combines

characteristics of broadcasting and point-to-point communications, since a copy of the data is sent to all recipients.

The rights of two separate entities are implicated in content streaming. First, the content owner typically desires that the content not be copied, i.e., that the content not be copied unless explicitly authorized. This requirement remains fixed over time. Second, the provider of the service that streams the content to users wants to ensure that only authorized users receive the stream, typically pursuant to a paid-for subscription or pay-per-view service, and that unauthorized users cannot access the content absent a subscription regardless of whether they are using copyright-compliant players. The latter requirement changes over time, since subscriptions typically are time-based and usually expire after a subscription period. The present invention thus recognizes the need for multiple enforcement domains, i.e., for a subscription enforcement domain overlaid on a copyright protection domain.

The present invention further recognizes that certain broadcast encryption schemes can be used in the streaming data application described above to achieve both copyright protection and subscription enforcement. Two such schemes are summarized here.

U.S. Patent No. 6,118,873, incorporated herein by reference, discloses a system for encrypting broadcast music, videos, and other content. As set forth therein, only authorized players, implemented either by hardware or software, can play and/or copy the content and only in accordance with rules established by the vendor of the content.

In the encryption method disclosed in the above-referenced patent, authorized players are issued software-implemented device keys from a matrix of device keys. The keys can be issued simultaneously with each other or over time, but in any event, no player is supposed to have more than one device key per column of the matrix. Although two players might share the same key from the same column, the chances that any two players share exactly the same set of keys from all the columns of the matrix are very small when keys are randomly assigned. The keys are used to decrypt content.

In the event that a player (and its keys) becomes compromised, deliberately or by mistake, it is necessary to revoke the keys of that player. Revoking a set of keys effectively renders the compromised player (and any clones thereof) inoperable to play content that is produced after the revocation.

Another broadcast encryption method is disclosed in the above-referenced parent application, in which players are grouped into (possibly overlapping) subsets, with each subset having a unique, long-lived subset key. Each player is assigned respective private information I_u . A short-lived session encryption key K is selected, and players that are not in a revoked set R are partitioned into disjoint subsets S_{i1}, \dots, S_{im} having associated subset keys L_{i1}, \dots, L_{im} . The session key K is encrypted with the subset keys L_{i1}, \dots, L_{im} to render m encrypted versions of the session key K . The players establish leaves in a tree such as a complete binary tree, and the subsets S_{i1}, \dots, S_{im} are induced by the tree.

With more specificity, in the parent application the players are initially partitioned into groups S_1, \dots, S_w , wherein "w" is an integer. A given transmission selects m such

groups as a "cover" for non-revoked players, with the cover being defined by the set of revoked players. The "cover" groups establish subtrees (either complete subtrees or a difference between two subtrees) in a tree. A player's private information I_u is preferably found as information i_j in a transmitted message that indicates that a player belongs to a subset S_{ij} of one of the groups S_1, \dots, S_w . In one embodiment, the information I_u consists of a player's position in the tree and the subset keys that are associated with ancestor nodes of the player. A subset key L_{ij} can then be obtained from or derived using the private information of the player.

In one embodiment referred to as the "complete subtree" method, respective groups correspond to all possible subtrees in the complete tree. Each player is assigned keys from all nodes that are in a direct path between a leaf representing the player and the root of the tree. In other words, each subset S_i includes all leaves in a subtree rooted at some node v_i , with at least each node in the subtree being associated with a respective subset key. In this embodiment, content is provided to players in a message defining a header, and the header includes at most $r * \log(N/r)$ subset keys and encryptions, wherein r is the number of players in the revoked set R and N is the total number of players. Moreover, each player must store $\log N$ keys, and each player processes the message using at most $\log N$ operations plus a single decryption operation.

In a second embodiment referred to as the "subset difference" method, respective groups of players correspond to a universe of sets S_1, \dots, S_w that can be described as "a first subtree A minus a second subtree B that is entirely contained in A". Each node in this

tree has a set of labels, one unique to the node and others that are induced by ancestor nodes. Each player is assigned labels from all nodes hanging from nodes in a direct path between the receiver and the root (at most $\log N$ labels from each such node), but not from nodes in the direct path itself. In other words, each subset includes all leaves in a subtree rooted at some node v_i that are not in the subtree rooted at some other node v_j that descends from v_i . One of the labels of the subset difference nodes for a particular player are provided to the player in a transmission as that player's private information. Using the labels, the player can generate the subset keys necessary for decryption.

With respect to the subset difference method of the parent application, the revoked set R defines a spanning tree. A cover tree T is initialized as the spanning tree, and then the method iteratively removes nodes from the cover tree T and adds subtrees to the cover tree T until the cover tree T has at most one node. The cover tree T is used to identify subset keys to be used in a particular transmission, with players evaluating the pseudorandom sequence generator to derive subset keys from the labels. Preferably, for processing efficiency revocations are processed in order from left to right such that only two revocations at a time must be kept in memory.

Other less preferred encryption systems have been provided. Examples of such systems include the tree-based logical key hierarchy systems disclosed in Wallner et al., Key Management for Multicast: Issues and Architectures, IETF draft wallner-key, 1997, and Wong et al., Secure Group Communication Using Key Graphs, SIGCOMM 1998. With more specificity regarding the methods of Wallner et al. and Wong et al., keys are

assigned by assigning an independent label to each node in a binary tree. Unfortunately, in the referenced methods some of the labels change at every revocation, and consequently are inappropriate for certain scenarios such as the stateless player scenario and moreover would require excessive encryptions and decryptions.

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SUMMARY OF THE INVENTION

The invention includes a computer system for undertaking the inventive logic set forth herein. The invention can also be embodied in a computer program product that stores the present logic and that can be accessed by a processor to execute the logic. Also, the invention is a computer-implemented method that follows the logic disclosed below.

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A method for multicasting data includes encrypting a title T with a title key K_T , and encrypting the title key K_T with a channel-unique key K_{cu} using an encryption function S to render a multicast data channel encrypted as $S_{K_{cu}}(K_T)$, $S_{K_T}(T)$.

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In a preferred embodiment, the channel-unique key K_{cu} is the result of a combination such as a hash of a channel key K_c and a session key K_s . Moreover, the session key K_s preferably is encrypted with a first encryption scheme B_{s1}^R to render a session key block.

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In the preferred embodiment, a player is provided with device keys K_d during or pursuant to activation of the player. Also, the player is provided with the channel key K_c and a session key block during or pursuant to registration of the player with a subscription

service. These provisions can be made point-to-point or as part of a broadcast. In any case, the player can determine the session key K_s from the session key block using the device keys K_d .

If desired, the method can include periodically refreshing the channel key K_c to enforce subscriptions, and selectively updating the session key block to revoke compromised players. The channel key K_c can be refreshed by encrypting a new channel key K_c' with an encryption scheme. For bandwidth considerations, the channel key K_c' can be sent in a message that is split, and it also can be refreshed using plural messages.

In a particularly preferred embodiment, at least the encryption scheme B_{s2}^R includes assigning each player in a group of players respective private information I_u , and partitioning players not in a revoked set R into disjoint subsets S_{i1}, \dots, S_{im} having associated subset keys L_{i1}, \dots, L_{im} . The scheme further includes encrypting the session key K_s with the subset keys L_{i1}, \dots, L_{im} to render m encrypted versions of the session key K_s . If desired, the encryption scheme B_{s2}^R may further include partitioning the players into groups S_1, \dots, S_w , wherein "w" is an integer, and the groups establish subtrees in a tree. The tree includes a root and plural nodes, with each node having an associated label. Each subset can include all leaves in a subtree rooted at some node v_i that are not in the subtree rooted at some other node v_j that descends from v_i . The revoked set R can define a spanning tree, and the encryption scheme can further entail initializing a cover tree T as the spanning tree, and iteratively removing nodes from the cover tree T and adding nodes to a cover until the cover tree T has at most one node. Or, each node can have a label

possibly induced by at least one of its ancestors, and each player can be assigned labels from all nodes hanging from a direct path between the player and the root but not from nodes in the direct path. Labels can be assigned to subsets using a pseudorandom sequence generator.

5 In another aspect, a method for enforcing copy protection compliance and subscription compliance includes providing players with respective device keys K_d that are useful for enabling copy protection compliance. The method also includes providing players with at least one channel key K_c that is useful for enabling subscription compliance, such that a player can decrypt content only if the player is both compliant 10 with copy protection and the player is an active subscriber to a content channel.

In still another aspect, a player for decrypting streamed content includes at least one device key K_d and means for decrypting a session key K_s using the device key K_d . The player also includes means for decrypting a channel unique key K_{cu} using at least the session key K_s . Moreover, the player can include means for deriving a title key K_T using 15 at least the channel unique key K_{cu} , with the title key K_T being useful for decrypting content.

In yet another aspect, a computer program device has a computer program storage device which includes a program of instructions that are usable by a computer. The device includes logic means for receiving private information I_u upon registration with a 20 content provider. Also, the device has logic means for subscribing to at least one content channel provided by the content provider, and logic means for receiving at least one

channel key K_c in response to subscribing to the channel. Logic means are provided for using at least the channel key K_c and private information I_u to decrypt content streamed over the channel.

The details of the present invention, both as to its structure and operation, can best be understood in reference to the accompanying drawings, in which like reference numerals refer to like parts, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of the present system;

Figure 2 is a flow chart depicting the dual enforcement domain concept;

Figure 3 is a flow chart of the overall encryption logic;

Figure 4 is a flow chart of the player logic; and

Figure 5 is a schematic diagram of the various states that a player can enter, along with a legend.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring initially to Figure 1, a system is shown, generally designated 10, for enforcing content copyright protection as well as subscription service protection. As indicated in Figure 1, players (only a single player 12 shown for clarity) receive content by multicast streaming from a subscription service provider 14, which in turn receives the content from a content owner 16. While the present invention focusses on streamed data,

it is to be understood that the principles of the present invention apply equally to other applications, such as to content that is downloaded in files without streaming.

The components 12, 14, 16 can be implemented by hardware or software. They can communicate via wired or wireless links, and can use computer networks such as the Internet to communicate with each other. Content from the content owner 16 can be provided to the subscription service provider 14 off-line, e.g., by shipping disks storing digital content from the content owner 16 to the provider 14.

By "broadcast" or "multicast" is meant the wide dissemination of a program from a source such as the subscription service provider to many players simultaneously over cable (from a satellite source), or wire, or radiofrequency (including from a satellite source).

It is to be understood that the logic shown and discussed below, which may be executed by a processor as a series of computer-executable instructions, is executed by processors associated with one or more of the components 12, 14, 16. The instructions may be contained on a data storage device with a computer readable medium, such as a computer diskette having a computer usable medium with computer readable code elements stored thereon. Or, the instructions may be stored on a DASD array, magnetic tape, conventional hard disk drive, electronic read-only memory, optical storage device, or other appropriate data storage device. In an illustrative embodiment of the invention, the computer-executable instructions may be lines of compiled C⁺⁺ compatible code.

Indeed, the flow charts herein illustrate the structure of the logic of the present invention as embodied in computer program software. Those skilled in the art will appreciate that the flow charts illustrate the structures of computer program code elements including logic circuits on an integrated circuit, that function according to this invention.

5 Manifestly, the invention is practiced in its essential embodiment by a machine component that renders the program code elements in a form that instructs a digital processing apparatus (that is, a computer) to perform a sequence of function acts corresponding to those shown.

Now referring to Figure 2, the overall logic for enforcing compliance in two domains - copy protection, and subscription - can be seen. Commencing at block 18, all 10 legitimate players are provided with respective keys and/or information that are useful for decrypting streamed content. The initial provision of device keys K_d is made for copy protection compliance. Block 20 represents subscription compliance, wherein the subset of players that have subscribed to a particular channel are identified, and the channel 15 content is encrypted such that only the subset of players subscribing to the channel can decrypt channel content.

Preferred implementations of the above are set forth below in reference to Figure 3. In the disclosure below, the notation B^R_{Sk} represents the encryption of a key K using 20 a broadcast encryption algorithm B under a symmetric cryptosystem S , such that players in a set R are excluded. The symmetric cryptosystem S preferably is a symmetric

cryptographic algorithm such as DES or SEAL. The resulting ciphertext can be referred to as a session key block.

Commencing at block 22, a session key K_s is encrypted with a copy compliance algorithm B^R_{S1} to render a session key block. In one embodiment, the copy compliance algorithm B^R_{S1} is the method set forth in the above-referenced patent and/or known as the C2 cipher available at www.4centity.com; in another embodiment, it is the method set forth in the parent application, and more particularly it is the subset difference method of the parent application.

Moving to block 24, a channel unique key K_{cu} can be generated from the session key K_s and a channel key K_c . In one non-limiting embodiment, the channel unique key K_{cu} is a hash of a concatenation of the session key K_s and channel key K_c .

In parallel with the operations of blocks 22 and 24, at block 26 a piece of content to be streamed, e.g., a video clip or movie, audio clip or movie, book, and so on, referred to herein as a "title", is encrypted with a title key K_T using the preferably symmetric algorithm S. At block 28, the results of blocks 24 and 26 are combined as follows. The title key K_T is encrypted with the channel unique key K_{cu} using the preferably symmetric algorithm S. Then, at block 30, the channel is encrypted as the encryption of the title with the title key ($S_{KT}(T)$) and the encryption of the title key with the channel unique key ($S_{Kcu}(K_T)$).

Having described how streamed content preferably is encrypted, Figures 4 and 5 show how the system configures players to receive and decrypt content while enforcing

both copy protection rules (by ensuring compliant players) and subscription protection. Commencing at block 32 in Figure 4 and as indicated at state 34 in Figure 5, an initially disabled player is enabled to an inactive state 36 by providing it with the code necessary to undertake the logic herein, and then activated to state 38 by providing it with a preferably unique set of device keys K_d in accordance with the above-referenced patent documents. This provision can be made during manufacture or subsequently during a separate activation step. If made separately, the device keys K_d can be transferred using, e.g., a public key exchange method P1.

As indicated at block 40 in Figure 4, the player can next move to a registered state 10 42 (Figure 5). In one non-limiting embodiment, this is done by the player sending public information about itself to the subscription service provider 14, which in return sends private information I_u to the player using a key exchange method $P1'$. In one non-limiting embodiment algorithms $P1$ and $P1'$ can be implemented using secure socket 15 layers with server-side certificates. One set of private information I_u preferably is provided for each subscription. In one illustrative embodiment, the private information I_u is the private information mentioned above and disclosed in the parent application.

Once a player is registered, at block 44 it can move to a subscribed state 46, wherein the player is subscribed to one or more channels from the subscription service provider 14. Ordinarily, the subscription process entails a payment from the player to the 20 service provider. The terms of subscriptions can vary in duration, content, cost, etc., with

the subscriptions being dynamic and each player potentially having several subscriptions simultaneously.

Although being entitled to a subscription, a player might not be actually receiving the content until it connects to the service at block 48 to enter an online state 50. The service provider 14 verifies that the player's subscription to the channel is valid for access control, and if valid, a current channel key K_c is sent to the player using a point to point exchange by means of a public key exchange method, denoted P2. The algorithm P2 can be implemented using the method of the above-referenced patent with a player-side media key block and secret media identification known only to the player and the service provider. This player-side media key block is not to be confused with the session key block.

Additionally, the player receives from the service provider the session key block, which as described above is an encryption of the current session key under the above-mentioned copy compliance algorithm B^R_{S1} . Along with the session key block, the player receives the current title key K_T , encrypted with the channel unique key K_{cu} as described above.

In an alternative embodiment, instead of a point-to-point transfer the data exchanged at block 48 can be broadcast in-band. Specifically, the encryption data can be periodically transmitted over the channel, so that online, authorized players can receive it and use it for decryption.

In any case, it may now be appreciated that an authorized player, while online, can receive and decrypt content at block 52 if it has not been revoked per the below discussion, and if it has a valid subscription to the channel. To decrypt the content, the player accesses its various device keys K_d and private information I_u as follows. In one illustrative, non-limiting embodiment, the session key K_s is derived from the session key block using the device keys K_d in accordance with the patent and/or parent application referred to above. Using the session key K_s and channel key K_c , the channel unique key K_{cu} is decrypted. In turn, the title key K_T is derived using the channel unique key K_{cu} , with the title key K_T being used for decrypting content. This process is represented by 5 listen loop 53 in Figure 5.

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The player can return to state 46 in Figure 5 by disconnecting, as indicated by the loop 54. Also, as discussed above the channel key K_c can be periodically refreshed, as indicated by the loop 56, by sending a new channel key K_c' only to subscribers of the channel. The new key preferably is sent using a message that is a function of the old 15 channel key K_c and a subscription compliance algorithm B_{S2}^R , namely, $S_{K_{cu}}(B_{S2}^R(K_c'))$. In one preferred, non-limiting embodiment, the subscription compliance algorithm B_{S2}^R is the above-summarized subset difference method of the parent application, with players 20 whose subscriptions have expired in the preceding period being included in the revoked set R of the algorithm. Such a refresh can be thought of as a minimal refresh, since it excludes only players whose subscriptions have just expired. Note that players not having

the current channel key K_c cannot decrypt the refresh message and therefore need not be included in the set R , thus reducing the size of the refresh message.

For the first time a player connects, to obtain the channel unique key K_{cu} the player uses its device keys K_d to obtain the session key K_s , which is then combined with the channel key K_c using the hash function to render the channel unique key K_{cu} . After 5 a refresh loop 56, a new channel key K_c' is computed (using private information I_u in accordance with the parent application, and more preferably with the subset difference method of the parent application) and combined with the session key, with the resulting new channel unique key K_{cu}' excluding all revoked and expired players.

10 When the player's subscription expires, the player is not provided with the refreshed channel key, causing it to return to the registered state 42 in Figure 5, as indicated by the loop 58. Subsequently moving from state 42 to state 46 and from state 46 to state 50 is accomplished in accordance with the disclosure above.

15 Players that are not connected during a refresh but still have a valid subscription can connect to obtain the current channel key. However, as recognized herein a rogue player can claim to have disconnected but in fact can continue to listen to the channel. To counter this, the service provider 14 maintains a list of all players that could have the current channel key, and these players can be excluded from the refresh (i.e., entered into the set R) if their subscriptions have expired. Players with a subscription that is just 20 expiring and that obtained the channel key through a connect transition at some point in

the past are considered to be connected for the purpose of exclusion in the current refresh transition.

Additionally, if a player whose subscription expired more than one refresh period in the past (and, hence, is not included in the exclude set R) obtains the channel key K_c illegally, it would be able to decrypt the new channel key K_c' and all future channel keys, as long it constantly monitors the channel. Accordingly, the present invention can exclude, in every refresh message, all players whose subscription will not be valid during the following period. Such a refresh can be thought of as a full refresh requiring a full revocation message. However, since the size of the exclude set R might be large, the following two optimizations can be used.

The full revocation message can be split and gradually sent over time. As a result, the refresh does not take effect instantaneously for all players. Also, players whose subscription expired long ago are sporadically revoked. That is, an intermediate revocation message is constructed that includes all players who must be revoked as well as many of the long-ago expirations that bandwidth permits.

In the event that it is discovered that the player has been compromised, it is necessary to revoke the player's device keys K_d and configure it to a revoked state 60, so that it cannot be used to make unauthorized copies of content. The copy compliance algorithm B^R_{SI} must be able to trace the originally licensed players whose device keys were compromised and revoke these players.

To revoke one or more players, a new session key block is generated that revokes all players that have ever been revoked, i.e., exclusion is cumulative. The content owner 16 can distribute the new session key blocks to the service provider 14, which is responsible for updating it for secure streaming. The new session key block is broadcast 5 in the clear to all connected players to update the session key block, as indicated by the loop 61; those who connect after the update can obtain the new session key block in a point-to-point exchange. Note that typically the same session key block is used by all compliant service providers for all channels.

When a revoked, connected player attempts to listen to any channel for which an 10 updated session key block has been provided, it cannot decrypt the new session key K_s' and thus cannot access the content. When this happens, the user of the revoked player must restart the entire process, since a revoked player is for all practical purposes the same as a disabled player in state 34.

As mentioned above, the preferred implementation requires a player to store a set 15 of device keys for content protection and a set of private information for each subscription service. As recognized here, this might exceed the capacity of smaller players, requiring that only a single enforcement domain be used, either copy protection or subscription protection.

For a copy protection domain only, keys are drawn from a tree and provided only 20 once. The channel key is transmitted to all players and can be decrypted by all; however, a compliant player will not use the key to decrypt content unless it is subscribed. The

refresh transition simply refreshes the channel key using the previous channel key. This method requires only a single set of keys at a player, requires a central agency to coordinate revocations, and should be designed to sustain many revocations.

For subscription domain only, all keys are drawn from a single tree, and there are no device keys. The unique set of keys is given to players at activation. During subscription the player and its keys are identified and a message containing the channel key is transmitted. At refresh, a revocation message excluding all players whose subscriptions is about to expire is multicast.

Because every service provider must be able to construct a revocation message, all providers must have the same keys. Therefore, this scheme uses public key techniques. Players that are found to violate compliance can be excluded from every message, thus effectively revoking those players.

It is to be understood that the principles disclosed herein can be applied to multicasting such as videoconferencing, with the service provider enforcing access control to the conference. Every node encrypts its messages using the same algorithms described in the listen state. A title can be equivalent to a message originating from one user, or the conference may be split into chunks of fixed duration. Compliance is used to ensure no unauthorized use of the conference content is made.

While the particular METHOD FOR ENSURING CONTENT PROTECTION AND SUBSCRIPTION COMPLIANCE as herein shown and described in detail is fully capable of attaining the above-described objects of the invention, it is to be understood

that it is the presently preferred embodiment of the present invention and is thus representative of the subject matter which is broadly contemplated by the present invention, that the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present invention is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular means "at least one", not "only one", unless otherwise stated in the claim. All structural and functional equivalents to the elements of the above-described preferred embodiment that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device or method to address each and every problem sought to be solved by the present invention, for it to be encompassed by the present claims. Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited as a "step" instead of an "act".

WE CLAIM: